A statement—originally, it may be, true in substance—is made that a certain type of foreign instrument is superior to any other; the statement grows to a legend and lives long after changes and developments have rendered it false or, at least, misleading; and the British instrument has to overcome much inertia of prejudice and fashion before it can secure the recognition which its merits deserve. It would be well if the leading scientific users of instruments would review from time to time their judgments of the quality and performance of instruments, so that improvements in British instruments may receive early recognition and the British manufacturer not be prejudiced by a belated preference for foreign instruments.

The present condition of the British scientific instrument industry is gravely compromised by the abnormal state of the international rates of exchange. Whatever legislative measures may be employed to help the industry over a difficult period, there can be no doubt that the most potent means of promoting the production of British scientific instruments equal to the best that the world can offer—a matter in which manufacturers and users are alike concerned—lies and must lie in an intensive and extensive application of scientific research to the fundamental scientific problems and the current technique of the industry. Other countries, notably Germany and America, we may be sure, will not neglect this. The leading British scientific instrument manufacturers have recognised the primary and paramount importance of scientific research. The British Scientific Instrument Research Association was founded in 1918, and its third annual report, which was reviewed in NATURE of November 17 last, gave ample evidence of the value to the industry of such an institution. It is true that, as is stated in the fifth annual report of the Committee of the Privy Council for Scientific and Industrial Research, "research cannot be expected to produce results at short and regular intervals"; but the Association has already produced results of immediate practical application and of economic benefit to the industry without losing sight of the fundamental researches, necessarily slower in coming to fruition, on which the progress of the industry must be based. Nor should it be overlooked that the co-operative research of the Association not only does not supersede, but stimulates and assists, the research work of individual firms which are members of the Association.

Moreover, where the Association, in view of its duty to the pressing needs of the industry, is unable to explore all the by-paths of pure scientific research that are opened out, arrangements have been made for extra-mural researches in the universities or kindred institutions for the prosecution of these relevant but more remote investigations. It must be remembered, too, that the Association, as the scientific centre of the industry, provides a needed *liaison* between the manufacturers and users of scientific instruments in this country, so that, on one hand, the manufacturers may be more fully informed of the needs of the users, and, on the other, the users may better appreciate the limitations imposed on manufacturers by the nature of materials and industrial conditions.

If the manufacturers will follow with patience and persistence the path of scientific research on which they have already made significant progress, there is every reason to hope that British scientific instruments generally will be, as many now are, supreme.

The History of Zeeman's Discovery, and its Reception in England.

Verhandeligen van Dr. P. Zeeman over Magneto-Optische Verschijnselen. Pp. xv + 341. (Leiden: Eduard Ijdo, 1921.)

TWENTY-FIVE years ago Dr. Zeeman, working at Leyden in the laboratory of Prof. Kamerlingh Onnes, achieved the epoch-making discovery which is now so abundantly familiar to physicists. Almost simultaneously he was appointed professor of physics at Amsterdam. To celebrate these events a volume of his collected papers, bearing on this branch of magneto-optics, has been published, under distinguished editorship, with a portrait and a few editorial notes and minor corrections.

This is the volume under review. It is a tribute to Prof. Zeeman from his friends and colleagues, on the occasion of the twenty-fifth anniversary of the announcement of his discovery to the Amsterdam Academy of Sciences on October 31 and November 28, 1896. It has an introduction in Dutch, dated October, 1921, which is signed by H. A. Lorentz, H. Kamerlingh Onnes, I. M. Graftdijk, J. J. Hallo, and H. R. Woltjer.

In commending this volume I would say that no one need be deterred from attending to it by reason of ignorance of the Dutch language: for our Dutch friends, with their well-known consideration, are polyglot in their publications, and there is plenty of English as well as French and German in the book.

The volume being mainly one of historical and permanent interest, it seems fitting to receive it with acclaim and to supplement it by an account of the reception and speedy appreciation of the discovery in England. For in a quarter of a century a new generation of physicists has arisen, many of them so intently occupied with their own admirable investigations that perhaps the origin of much of our present knowledge of Nature is liable to be submerged. Especially may they fail to realise the anticipations of the great theorists, which enabled a little seed-fact to fit immediately into its cranny and quickly to develop magnificent blossoms.

As to its reception here, the beginning was extremely modest, and may be narrated thus: On December 24, 1896, there appeared in NATURE, vol. 55, p. 192, the usual report of a meeting of the Royal Academy of Sciences of Amsterdam, and in a paragraph abstracting a number of other communications to that society the following sentence occurs:—

> "Prof. Kamerlingh Onnes communicated two papers: (*a*) by Dr. Zeeman, on the influence of magnetisation on the nature of the light emitted by a substance. Pursuing a hint given by Faraday, several experiments were tried. The principle was this: the light of the electric arc, being sent through a heated tube containing sodium vapour, is analysed by a Rowland's grating. The tube is placed between the poles of an electro-magnet. When acted on by the magnet, a slight broadening of the two sodium lines is seen, tending to show that forced vibrations are produced in the atoms by the action of magnetism; (*b*) by Dr. J. Verschaffelt on capillary ascent," etc.

This sentence, included in a long paragraph, was probably the first announcement in England; but it was so inconspicuous that it could scarcely have attracted much attention, had not Sir Joseph Larmor, this year's Copley medallist, been on the look-out for an effect of this kind. He had previously perceived that such a result was necessary theoretically; a fact which is demonstrated by, among other things, the following passage reproduced on p. 203 of his book, "Æther and Matter":—

> "Each absorption line say of sodium vapour in a magnetic field will thus be more or less widened, and its main position also slightly shifted but only to a higher order of small quantities: and the same will apply to each line in the emission spectrum."

Larmor had indeed gone on to calculate the amount of displacement or broadening to be expected, and had found the effect too small to be observed; for, like everyone else at that time, he considered that the radiating body must be an atom or part of an atom with an $e/m = 10^4$. So directly Zeeman got an effect, and found that the e/m was really of the order 10^7, Larmor perceived that, not the whole atom, but the charge only—the electron part of the ion, or an electron itself—was a free radiator, and wrote to me suggesting that I should examine and confirm the result. In a week I had done so, with such appliances as were to hand; though not without sufficient difficulty to make me realise the naturalness of Faraday's failure to see anything—he being wholly unguided by theory—and to admire the skill of Zeeman in detecting the effect.

Prof. Zeeman must soon afterwards have communicated his observations to the Physical Society of Berlin; for in NATURE, vol. 55, p. 347, is a translation of a short paper by him, dated from Amsterdam and thanking Prof. K. Onnes for his interest in the work.

The first official notice in England occurs in the Proceedings of the Royal Society for February 11, 1897, when a note by me entitled "The Influence of a Magnetic Field on Radiation Frequency" was received and read on the same day. It gives an account of my repetition of Zeeman's experiment and directs attention to Prof. Lorentz's theory of it, together with his brilliant prediction about polarisation of the modified lines, and its experimental verification (see Proc. Roy. Soc., vol. 60, p. 513). It is followed, on p. 514, by a theoretical note by Sir Joseph Larmor, in which he emphasises the "electron" aspect of the matter, and its reciprocal relation to Faraday's first magneto-optic effect. He also directs attention to previous memoirs by Helmholtz in 1893, and by Lorentz in 1892 and 1895, especially the former; and he cites p. 813 of his own splendid Memoir in Phil. Trans., A, 1894.

I also communicated a much longer article to the *Electrician* for February 26, 1897, vol. 38, p. 568, under the heading, "The Latest Discovery in Physics": an article which I should like to reproduce here, for I venture to say that portions of it are worthy of reference by anyone interested in scientific history. The freedom with which we all spoke of electrons and their motions in those days rather surprises me, seeing that the unit charge was not isolated and clinched until 1899. But, of course, the theoretical work of Dr. Johnstone Stoney and others had long preceded this date.

There was no excuse for not fully understanding the main perturbations of spectrum lines when once the idea of electrons revolving like satellites in regular orbits, obedient to astronomical laws, had been grasped; for Dr. Johnstone Stoney's remarkable paper, entitled "On the Cause of Double Lines and of Equidistant Satellites in the Spectra of Gases," was in my possession. (It will be found in the Transactions of the Royal Dublin Society for 1891, vol. 4, Series II., pp. 563–608.)

But the difficulty was that at that date we all—

except perhaps Larmor and Lorentz—thought of an electron as of something attached to an atom, making it an ion, in accordance with Faraday's electrolytic ideas; and the notion of a free satellite electron, inside the boundary of an atom, was of later growth. In fact, it was a development largely brought about by Zeeman's discovery.

Parenthetically I may remark that there is some risk of Dr. Stoney's contributions to science being overlooked, partly because the Transactions of the Royal Dublin Society are not so readily accessible as some other publications, and partly because he expressed himself in terms and ways not always in accordance with ordinary custom. Let me put on record here, therefore, that, at that early date, 1891, he examined dynamically the problem of satellite electrons perturbed from a simple orbit by unknown forces. He deals with elliptic, apsidal, and precessional motions, with periodic changes in each, and clearly depicts the double and treble and quadruple lines which would result.

He is not dealing with perturbations excited by some definite outside physical cause, such as a magnetic field applied to the source, but with the normal series of lines observed by spectroscopists—Balmer, Kayser and Runge, etc.; and the inference he draws is that many of the known groups can be accounted for on the analogy of astronomical perturbations. The problem he set himself is thus worded (p. 569):—

> "We shall accordingly, for the present, regard certain points in the molecules of the gas as acting dynamically on an æther capable of receiving and transmitting only transverse vibrations, and we have to inquire what motions of these points within the molecules would impart to the medium the oscillations which correspond to the observed lines in the spectrum."

To return from this digression. Whether on account of my article in the *Electrician*, or because I had written direct to Prof. Zeeman (probably for the latter reason), he sent me the MS. of a finished paper of his, giving the experimental details and also his version of Lorentz's theory developed on equations like those of the Foucault pendulum; and this paper I at once communicated to the *Phil. Mag.* for March, 1897 (vol. 43, p. 226), adding a brief footnote to say that I had verified the author's results so far as related to emission spectra and their polarisation. This memoir is now reproduced as the first in the volume of Zeeman's collected papers just issued, and it is printed in four languages—Dutch, English, French, and German; but the English and other versions contain an appendix, not in the original Dutch, giving an account of the attempts made long ago by Faraday, and likewise a theoretical anticipation by Prof. Tait in 1875 (an anticipation based on Kelvin's general theory of magneto-optic rotation), together with the record of a contemporary failure experimentally to detect any such effect. This appendix also removes from competition some apparently similar but not identical observations made by a M. Fievez.

It is of interest to find that in this remarkable and fundamental paper by Prof. Zeeman the possible effect of solar magnetism on the sun's radiation is indicated as a subject for inquiry—a development afterwards so brilliantly followed up by Prof. Hale.

In May, 1897, I communicated another note to the Royal Society (Proc. Roy. Soc., vol. 61, p. 413), in which details of the appearance of the lines are given, and the curious complexity of some of them; also, which surprised me, a difference between the behaviour of the components of the pair of sodium lines. The red cadmium line was also examined, and other spark spectra. The substance of this paper is reported in NATURE, vol. 56, p. 237. And in the same month (on May 19) I exhibited the effect at the Royal Society soirée, as appears from the following entry in the Year-book for 1897, p. 119:—

> "*Demonstration of Zeeman's Discovery of the Broadening of Spectrum Lines by the Action of a Magnetic Field on the Source of Light. Exhibited by Prof. Oliver Lodge, F.R.S.*
>
> "Sodium lines produced by an oxyhydrogen flame between the poles of a powerful magnet are examined by means of a Rowland concave grating (the one with which Mr. George Higgs photographed the solar spectrum), and can be seen to broaden whenever the magnet is excited. A nicol or other analyser shows that the light of changed refrangibility is polarised, as it would be if the source of radiation consisted of revolving electrified particles whose motion is accelerated or retarded by magnetic lines of force through the plane of motion.
>
> "Recent Observations.—By reason of reversals, the usual appearance of each sodium line is as if it were doubled; the magnetic field makes it appear triple, or even quadruple. A nicol properly oriented removes the magnetic effect. D_1 shows it more sharply than D_2. The new lines intrude into the middle, after the fashion of Newton's rings."

It may seem from this that the observation of doublets and triplets, as indicated by the theory, was made by me; but that I disclaim, as appears in the volume under review, p. 101, since, though I saw something like the real effect, I did not apprehend it clearly as a pure precessional effect (akin to that which Dr. Johnstone Stoney had worked out long ago), and was inclined to suppose that the magnetic acceleration and retardation of frequency, acting on a random collection of molecules, would be likely to cause a confused broadening (see the *Electrician* of February 26, 1897, vol. 38, top of p. 569). I was still too much influenced by the idea of random atomic motions, instead of precise electronic orbits.[1] The real effect, as perceived in advance by Lorentz and realised clearly by Zeeman, was much sharper and more beautiful than that, and my suspicion of a more complex or mixed effect was unnecessary; the simple Lorentz theory served, just as cited in that same article of mine in the *Electrician* (except that I made a slip and gave a value for the perturbed frequency which I correct in the second following issue, p. 643 of the same vol. 38. Some remarks on e/m, interesting from an historical point of view, will also be found in that issue, and an extremely short formulation of the theory, thus: "Magnetised change of centripetal force, $e\mathrm{H}r\omega = mrd\omega^2$, whence $d\omega = e\mathrm{H}/2m$." Here also is the record of a temporary slip about the sign of the effect, made by Zeeman himself, for he at first announced that the radiating particle was a *positive* charge).

At the same time, a pure doubling or a tripling, characteristic of a truly circular or elliptic orbit perturbed by an apsidal or a precessional motion, is not the last word; for, though this is the standard of simplicity, each line in the spectrum is liable to have peculiarities of its own, depending on the nature of the electronic orbit which is magnetically perturbed; and hence there is found, not indeed mere broadening, but a quadrupling, sextupling, and other varieties of effect, such as are now well known, but which I confess surprised me when first I saw their indications.

In the *Phil. Mag.* for December, 1897, is an important theoretical paper by Sir Joseph Larmor, "On the Theory of Magnetic Influence on Spectra, and on the Radiation from Moving Ions." Towards the end of this paper he deduces his fundamental expression for radiative power, as proportional to square of charge and square of acceleration. Non-radiation from charges moving at uniform speed *seems* to be indicated—which would be very convenient in making unperturbed atoms permanent—but unfortunately centripetal acceleration seems equally destructive to their constitution, were it not for the modern device of quanta.

In this same volume of the *Phil. Mag.* (vol. 44, pp 55 and 255) are two additional papers by Zeeman, also reproduced in the book under review, constituting the real publication of the occurrence of definite doublets and triplets in the magnetic field; and they are followed in this book by another one giving metrical results obtained photographically.

Photographic records of the effect were, indeed, tried for by other experimenters, though without success (see NATURE, vol. 56, p. 420). In NATURE, vol. 57, p. 173, however, Thomas Preston reports complete success, in Dublin, with a fine grating belonging to the Royal University of Ireland, mounted in accordance with Rowland's geometrical-slide design. But on p. 192 of the same volume a meeting-report shows that Zeeman had exhibited specimens of similar photographs at the Amsterdam Academy a month earlier; and he was now able to apply the photographic method to the obtaining of more exact measurements, as mentioned in the *Phil. Mag.* for February, 1898, p. 197. See also Preston, p. 325 of the same volume (vol. 45), by whom a plate showing the various appearances with great distinctness is submitted. A few pages further on (p. 348) is a communication, which still further emphasises complexities and individual peculiarities in the magnetised lines, by Prof. Michelson, who here begins to apply to them his remarkably powerful "visibility" test, which was first elaborated in the *Phil. Mag.* for September, 1892 (vol. 34, p. 280), as a sequel to his earlier more theoretical paper in April, 1891, and is now employed with such skill and brilliant success at Passadena to measure the diameter of stars.

In further papers by Zeeman the spectrum of *iron* is specially examined, and a lack of symmetry detected in some of its lines. And presently the resolving power of the Michelson echelon is pressed into the service for the further examination of details, with results which are described and expounded through the remaining 200 pages of this interesting memorial volume.

The extreme importance of Zeeman's great discovery, and the admirable way in which he worked it out with the inspiring theoretical assistance of Prof. H. A. Lorentz—so that theory and experiment went hand in hand, as it is to be wished they did more often—may be allowed to justify and excuse this somewhat personal welcome of its twenty-fifth anniversary by an English physicist.

OLIVER LODGE.

The Kaiser Wilhelm Institute.

Festschrift der Kaiser Wilhelm Gesellschaft zur Förderung der Wissenschaften zu Ihrem zehnjährigen Jubiläum Dargebracht von ihren Instituten. Pp. iv+282. (Berlin: Julius Springer, 1921.) 100 marks.

THE Kaiser Wilhelm Gesellschaft zur Förderung der Wissenschaften owes its origin to the action of certain leading industrialists

---

[1] Incidentally and generally, it cannot be unknown, but it seems to be ometimes overlooked, that every *regularity* tends to evade the equipartition of energy difficulty: for Maxwell's proof requires the motions to be not only interchangeable, but also completely random.